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Selecting sustainable renewable energy source for energy assistance to North Korea

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ABSTRACT

Renewable energy (RE) is the best sustainable energy solution South Korea can provide to assist North Korea in overcoming its chronic energy shortage. Designed as a follow-on research to Sin et al. [1], a survey was conducted with a panel of experts consisting of various disciplines and affiliations using the analytic hierarchy process (AHP) with benefit, opportunity, cost, and risk (BOCR).

The results showed the panel viewed security as the most important factor among the strategic criteria. For the level 1 attributes, the panel showed no significant differences of opinion among the different alternatives; however, cost showed to be the most important factor for the panel. The panel chose wind power as the best alternative source of energy for North Korea; however, there were some differences in opinion among the sub-groups of the panel depending on the composition and the expertise of the sub-group.

Compared to other studies on the similar topic, this research stands out in that the research results were derived using AHP and BOCR and that the panel was composed of both Korean and foreign experts on North Korea affiliated with state-run research organizations, armed forces, non-governmental organizations, academic research organizations, private consulting firms, and journalism. The research arrived at the conclusion that the following factors must be considered as South Korea designs its future North Korean energy assistance policy: (1) RE assistance for North Korea can take on various forms; hence, experts consulted during the design, writing, and implementation phases of the policy in question must possess knowledge and expertise in the appropriate technology and methodology being considered; (2) possibility of a sudden destabilization of the Northeast Asian security paradigm due to the collapse of North Korea; and (3) continued nuclearization of North Korea.

Contents

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1. Introduction

North Korea has been facing an energy crisis that it has not been able to solve through internal means [2,3]. While there is a desperate humanitarian need to provide North Korea with energy assistance, there are also numerous prerequisite issues that need to be addressed. Past and current energy assistance policies for North Korea, such as KEDO, heavy fuel oil aid, and direct power transfer, that the international community (to include South Korea) have implemented do not provide a fundamental or a permanent solution to resolving North Korea's energy problems. Energy assistance policies utilized thus far has faced several problems [4,5]. The outdated facilities and aging infrastructure of the North Korean energy sector make direct energy transfer (heavy oil and power) ineffective. South Korea and the international community discovered the truly decrepit nature of North Korea's energy infrastructure during the KEDO light-water reactor project [6]. North Korea has made a concerted effort to improve the situation; however, it has had little to no effect. Heavy fuel oil transfer has been delayed due to social and political controversies the heavy fuel oil transfers spark internal to the donor nation-states as well as the shortage of fuel storage facilities in North Korea [7]. There is a need for the North Korean government's political and physical will to truly resolve its energy shortage problem. As such, any policy planner who is working to implement an energy assistance policy for North Korea must first determine the North Korean Government's policy direction and then seek to find a cooperative framework that is compatible with it. Furthermore, the future energy assistance policies for North Korea, instead of being pedestrian short-range policies, must encourage internal changes and development of North Korea and fundamentally resolve the North Korean energy crisis by providing new energy technology transfers, facility and equipment support, infrastructure acquisition and expansion, and by encouraging international cooperation.

RE is the most appropriate energy to resolve the North Korean energy shortage while overcoming the various issues involved with providing North Korea with energy. First reason is that the inter-Korean RE cooperation would be consistent with the policy direction of the North Korean government. Secondly, technology transfer effects can be expected beyond the one-dimensional or simple energy transfer. Thirdly, considering the state of the energy infrastructure and T&D network of the North Korea, RE, which utilizes localized energy system, is a reasonable alternative [8–10]. Fourthly, North Korea has already shown its desire to actively develop RE and North Korea has high potential for future RE development [11,12]. Fifthly, the inter-Korean RE cooperation can influence publicity both domestically here in South Korea and internationally; avoid the pitfalls of the issues related to nuclear problem, international relations, or technology diversion to the North Korean military; and North Korean government is more likely to be amenable to the construction of RE facilities within its borders.

RE assistance to North Korea is expected to bring about the international community's political cooperation out of the spirit of humanitarian assistance. Economically, South Korea's RE market can potentially benefit and expand from increased demand. Over the long-term, South Korea can prepare for the unification of the peninsula as it constructs and upgrades North Korea's energy infrastructure [13]. Other researches in this subject have shown that the inter-Korean RE cooperation is appropriate because RE utilizes localized energy system; is consistent with North Korea's policy direction; and is appropriate for the environmental conditions of North Korea. The core of the North Korean RE technology development policy, in fact, is built around balancing energy, environment, and ecological aspects, and the aim of the North Korean energy policy is to satisfy environmental requirements while satisfying demand and security requirements by increasing production of sustainable domestically produced energy – a very sound policy goal. The international community has already provided North Korea with wind power, solar power, solar heat, and biogas facilities, which were in line with the existing North Korean RE policy goals.

While other researches on this subject conducted surveys and collected experts' opinions [14] or selected alternatives using qualitative methods [15], this research, in contrast, surveyed technical and political experts' opinions using AHP with BOCR method focused on selecting those RE sources that can be utilized for sustainable inter-Korean energy cooperation for the mid- and long-term, with the ultimate goal of energy independence for North Korea through technical cooperation that is firmly grounded in a theoretical methodology.

The concept of "sustainable" was important for this research because the North Korean energy problem cannot be solved by one or two simple aid plans. To solve North Korea's energy problem, one must be able to supply enough energy to solve the daily energy shortage in the short-term and an internal system must be established that can meet the future energy demands without external assistance in the long-term. It is in this perspective, this research defined the characteristics of new and renewable energy that can satisfy the needs for short-term energy transfer, mid-term energy relief, and long-term energy independence as the concept of "sustainable."

2. Methodology

2.1. Analytic hierarchy process (AHP)

Analytic hierarchy process (AHP) is one of the decision making tool which is designed to make decision between several alternatives with multiple factors using multi-dimensional evaluation criteria. AHP is proposed by Tomas. L. Saaty in late 1960s. AHP provides a comprehensive framework by considering quantitative and qualitative factors based on the intuitive and rational/irrational judgments of the respondents. The best feature of the AHP is that it divides complex issues into key factors and sub-factors by layering, and then calculates the weight of the factors with the pairwise comparison [16]. Other researchers have utilized AHP for research examining subjects such as multi-criteria decision making in energy planning [17], evaluation of energy sources for heating [18], and making sustainable energy development strategies [19].

A study with AHP starts with identifying issues and set problems into hierarchical factors. Then, pairwise comparison is conducted between adjacent low level factors based on the high level factors. Priorities are calculated by pairwise comparison and as a result of synthesizing the results, full priorities are calculated. In the final step, hierarchical consistency is measured and dependency between factors is considered. AHP method, basically, is a systemic method to conduct pairwise comparison between factors.

2.2. AHP with BOCR

One of the difficulties of the AHP analysis is the selection of factors. Especially in a not previously studied field or a field where no similar case studies have been conducted. In these cases, a separate survey is carried out just to select the factors to examine. The problem is that there are cases where no consensus can be built among the panels participating in the survey. The AHP with BOCR is a useful method to solve this problem.

In early days, *risk* is added to B/C ratio from the Benefit and Cost so the $B/(C \times R)$ ratio was used for the preferences from each hierarchy. Afterwards, fourth factor, *opportunity* is added [20] to enable the BOCR analysis to use $(B \times O)/(C \times R)$ ratio.

General AHP analyses tend to only consider the positive priority in the decision-making. Let's take the decision-making process for purchasing a car, for example. For the person making a choice of what car to buy, he has to consider the cost of different cars in his decision-making process. In this case, cars that *cost* less to the buyer could translate into higher *benefit* for him. In other words, negative priority in this case can be measured as a positive priority, forming a reverse relationship. This is not always the case, however. In a pleasure–pain relationship or the gain–loss relationship, for example, are relationships that do not form a reverse relationship. This is because lack of pleasure does not necessarily represent pain, nor does lack of gain necessarily represent a loss. Additionally, even a minute amount of pain is infinitely inferior to pleasure. These examples demonstrate the necessity that negative priority must be considered in AHP analyses.

Because the factors that exhibit negative priorities, such as *cost* and *risk*, have opposite values from those factors that exhibit positive priorities, a different method is needed to consider the factors that exhibit both priorities simultaneously. During decision-making process, there are cases where one must conduct pairwise comparison of factors that are complete opposites of each other (such as *benefit* and *cost*). Here, while benefit measures which alternative provides more benefit in a pairwise comparison where as the cost measures which alternative incurs less, or more, *cost*.

This tendency applies to *opportunity* and *risk* as well. In general, *benefit* (*B*) is a factor that is associated with decision-making while *opportunity* (*O*) is a factor that contributes to the decision for *B*. *Cost* (*C*) is a factor that causes *risk* (R) while R is a factor that denotes the problems one would face [21].

Full BOCR analysis is similar to the SWOT analysis. *S* (s*trong point*) and *O* (*opportunity*) are defined as entrance to a new market or other friendly situation. *W* (*weak point*) attempts to define the negative factors involved in the SWOT analysis, but it does not explain all the circumstances. *T* (*threat*) represents social competition that must be handled or development of hostile/negative situation. In BOCR analysis, *R* (*risk*) represents factors that arise as a result of development of hostile/negative situation in the future while *C* (*cost*) represents factors that arise as a result of current loss or relatively predictable development of hostile/negative situation.

Generally, five methods exist to make use of each BOCR weight [22].

1. Additive:

$$P_i = bB_i + oO_i + c\left(\frac{1}{C_i}\right)_{\text{Normalized}} + r\left(\frac{1}{R_i}\right)_{\text{Normalized}}$$

   where B_i, O_i, C_i, and R_i are the synthesized results of alternative *i* under merit *B*, *O*, *C* and *R*, respectively, and *b*, *o*, *c* and *r* are normalized weights of merit *B*, *O*, *C* and *R*, respectively.
2. Probabilistic additive:

$$P_i = bB_i + oO_i + c(1 - C_i) + r(1 - R_i)$$

3. Subtractive:

$$P_i = bB_i + oO_i - cC_i - rR_i$$

4. Multiplicative priority powers:

$$P_i = B_i^b + O_i^o\left[\left(\frac{1}{C_i}\right)_{\text{Normalized}}\right]^c\left[\left(\frac{1}{R_i}\right)_{\text{Normalized}}\right]^r$$

5. Multiplicative:

$$P_i = \frac{B_i O_i}{C_i R_i}$$

For this research, *Subtractive* and *Multiplicative* methods were used to derive and compare the results.

BOCR can be applied to ANP (analytic network process) as well as AHP. ANP is a method that identifies the relationship among factors and measures the amount of mutual influence one factor has on others. Recent AHP with BOCR included solar-wind hybrid system selection research [23] and research on construction of wind power complex [22]. Recent ANP with BOCR included national energy policy implementation modeling research [24], research on selection of information system project for the firm [25], research on selection of urban waste landfill location [26], and alternative fuel for residential home heating research [27].

2.3. Application of BOCR

Research that utilizes AHP with BOCR as the upper level attributes begins the same way as researches that utilizes ordinary AHP – determine the problem and set the factors associated with the problem by hierarchical layers. Different from the ordinary AHP, in AHP with BOCR, one must establish strategic criteria. Strategic criteria is designed to set the weight of each BOCR factors and differs from the internal attributes of AHP. Another difference is that in BOCR, pairwise comparison is conducted among the lower level attributes. Priority is given to each attribute based on these pairwise comparisons and the priority of the attributes is ranked ordered by combining the results of each pairwise comparisons. Finally, hierarchical consistency is measured to ensure the validity of the analysis. Moreover, one must also consider the dependency problems between the factors. This process can be explained in 10 steps as seen below [22]:

Step 1. Select and define the problem: Establish expert groups and clearly define the problem that is to be examined.
Step 2. Establish the control hierarchy for the problem. Control hierarchy includes strategic criteria, basic criteria to evaluate the problem, and four factors of BOCR. Strategic criteria are selected based on the characteristics of the research. In their 2003 research to determine the alternatives for Central American trade, Saaty and Ozdemir selected *economics*, *security*, and *political* as their strategic criteria. In their 2009 research on wind-farm, Lee, Chen, and Kang used *performance*, *business drivers*, and *socio-economic need* as their strategic criteria.
Pre-Step 3. Decide on the priorities for strategic criteria.
Step 3. After determining the strategic criteria, conduct a survey to determine the weight for each strategic criteria's BOCR, construct a pairwise comparison matrix, and assess their priorities. Consistency property of the matrix must be examined afterwards and if the matrix is found to be inconsistent, another survey is conducted.
Step 4. Determine the weight by *B*, *O*, *C*, and *R* for each strategic criterion.
Step 5. Determine the normalized priority for BOCR by multiplying the weights determined from step 4 and the assessed priority from step 3.
Step 6. Define the lower level attributes for BOCR that agree with each item of BOCR and would contribute to the achievement of the project's goal by consulting with experts and related documents.
Step 7. Prepare the survey that pairwise comparison based on BOCR hierarchy and preferences for each alternative.
Step 8. Assess the relative priority for each lower level attributes. Like in step 3, endow the priority for each attribute and then decide on the weight.
Step 9. Determine the priority for each alternative by lower level attribute. Assess relative importance and weight for each alternative by phase through this process.

Step 10. Finally, each alternative's priority is determined based on the normalized weights of *B*, *O*, *C*, and *R*.

3. Research

3.1. Survey construction and panel selection

AHP is a method that obtains data through surveys; therefore, the entire research is influenced by the composition of the survey panel, making panel selection an extremely important phase of the research. For this research, the panel was composed of both Korean and foreign university professors, state-run research institute researchers, representatives of international and non-governmental organizations, representatives of private think tanks and consultation companies, government officials, and officers of Armed Forces who have expertise in North Korea. The panel was subdivided into sub-panels of engineers, political scientists, and Korean Peninsula security experts. Since the focus of this research was RE assistance to North Korea, a panel of engineers with expertise in new and renewable energy, a panel of Korean policy and political scientists who have expertise on inter-Korean assistance issues, and a panel of foreign experts who can provide a different perspective into the Korean Peninsula problems was extremely appropriate to answer the questions at hand. Additionally, we expected very insightful comments from these panels on the issues related to RE assistance to North Korea as well as inter-Korean and international issues surrounding North Korea. A special caution was used in selecting the panel members for the engineers' sub-panel to eliminate any bias that could arise due to unbalanced concentration of experts in a particular energy source.

This research started out with the purpose of determining the most sustainable RE source that can be provided to North Korea as a part of the energy assistance. To clearly define the parameter of the problem and reduce the bias that can be generated by arbitrary interpretation of the problem set by the panel members, we made some crucial assumptions. The first assumption we made was the North Korea's nuclear problem will be peacefully resolved in the long-run. Secondly, while North Korea has largely adapted to the international rule of order, unification of the Korean Peninsula has not been realized yet and the international community, to include South Korea, does not entirely trust it. Thirdly, RE assistance to North Korea is a long-term issue. Fourthly, technology and facilities provided to North Korea is limited to those available and made in South Korea. Finally, first iteration of survey was conducted with the panel members to verify and adjust the validity of these assumptions.

We constructed the draft hierarchy for the first survey by examining pre-existing documents, researches and brainstorming. Upper level attribute was composed of *benefit*, *cost*, and *risk* (meaning that the upper level attribute seeks to determine the *benefit*, *cost*, and *risk* associated with providing RE assistance to North Korea). Additionally, the upper level attribute was associated with three lower level attributes. We also decided the strategic criteria for the AHP with BCR (BOCR) would be *political*, *security*, and *humanitarian* (Fig. 1).

Strategic criteria are the very basic criteria used to assess the problem [22]. Usually the criteria are considered as sub-goals of the problem; in this case, it is "what do we want to achieve from RE assistance to NK" or "what is the most important factor that we should consider with RE aid to NK?" Through internal discussion and brainstorming, following 3 factors were selected as strategic criteria: political, security and humanitarian.

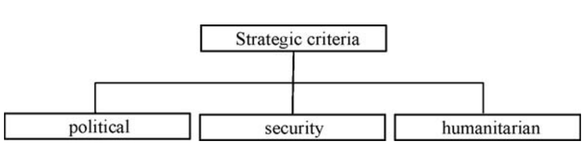

Fig. 1. Strategic criteria.

3.2. First survey

The purpose of the first survey was to ascertain the panel's opinion of the draft hierarchy. For each factor presented, the panel answered with *needed*, *not needed*, or *adjust meaning*. The panel members were also provided the opportunity to express their opinions freely on the survey so they can recommend ways to improve the final attribute model for the second survey and to improve definition of criteria.

The first survey was conducted as a preparatory step to ascertain the factors that needs to be considered during the primary research with the assumption that RE assistance to North Korea has been implemented and the currently existing issues concerning North Korea continues to exist. This allowed us an opportunity to examine if we missed any factors that needs to be considered, or if we have been considering unnecessary or duplicate factors, as well as an opportunity to determine whether the explanation for attribute modeling was sufficient. Diverse recommendations were made by the panel during the first survey and we adjusted our draft hierarchy and arrived at our final hierarchy, which reflects the results of the first survey (Fig. 2).

3.3. Second survey

The Second survey was designed based on the final hierarchy constructed as a result of the first survey to determine the weight of each attribute and the priority of the final alternative selection. Pairwise comparison was used to assess the weights between attributes and the section for final alternative was procured. The total panel for the second survey consisted of the panel members from the first survey and numerous other experts on North Korea who did not participate in the first survey. The collection rate for the second survey was 71.4%. The results of the second survey are shown in Tables 1–4.

There were some rare cases where the priority of the final alternative changed based on the methods (subtractive or multiplicative) used to calculate the weights of first level attributes. These occurrences can be seen on ranks 2 and 3 of *Total* column of Table 4 as well as the ranks 6 and 7 of *Political experts Total* column of Table 4.

Table 1
Result: weights of strategic criteria.

Strategic criteria	Total	Engineers	Political experts		
			Total	Korean	Foreign
Political	0.209	0.196	0.213	0.201	0.221
Security	0.541	0.522	0.548	0.608	0.495
Humanitarian	0.250	0.282	0.239	0.190	0.284

Table 2
Result: weights of BCR.

	Total	Engineers	Political experts		
			Total	Korean	Foreign
Benefit	0.339	0.296	0.360	0.385	0.346
Cost	0.343	0.410	0.321	0.322	0.317
Risk	0.317	0.294	0.319	0.293	0.336

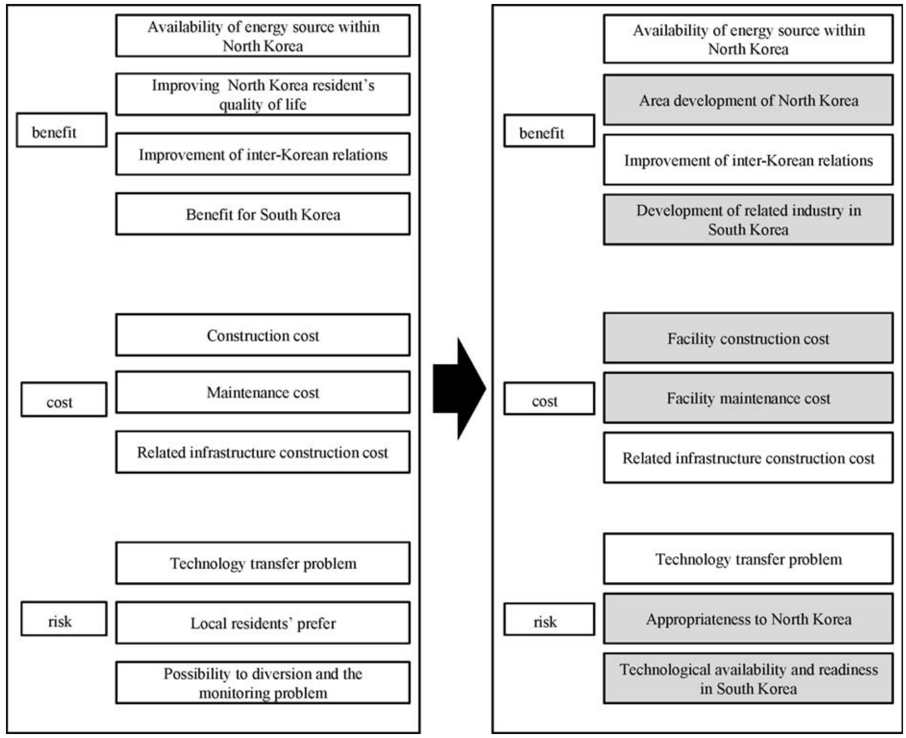

Fig. 2. Final attribute model.

Table 3
Result: weights of attributes.

Level 1 attributes	Level 2 attributes	Total	Engineers	Political experts		
				Total	Korean	Foreign
Benefit	B1. Availability of energy source within North Korea	0.092	0.060	0.074	0.088	0.109
	B2. Area development of North Korea	0.058	0.046	0.032	0.042	0.078
	B3. Improvement of inter-Korean relations	0.108	0.085	0.148	0.131	0.095
	B4. Development of related industry in South Korea	0.093	0.152	0.092	0.088	0.064
Cost	C1. Facility construction cost	0.092	0.191	0.060	0.060	0.060
	C2. Facility maintenance cost	0.109	0.050	0.131	0.124	0.141
	C3. Related infrastructure construction cost	0.132	0.090	0.137	0.151	0.127
Risk	R1. Technology transfer problem	0.132	0.208	0.096	0.074	0.130
	R2. Appropriateness to North Korea	0.112	0.043	0.146	0.146	0.133
	R3. Technological availability and readiness in South Korea	0.064	0.053	0.065	0.090	0.043

Table 4
Result: rank of alternatives.

Rank	Total	Engineers	Political experts		
			Total	Korean	Foreign
1	Wind	Solar (heat)	Wind	Small hydropower	Wind
2	Solar (light) [solar (heat)]	Geothermal	Solar (light)	Waste	Solar (light)
3	Solar (heat) [solar (light)]	Solar (light)	Solar (heat)	Biogas	Solar (heat)
4	Small hydropower	Small hydropower	Small hydropower	Geothermal	Small hydropower
5	Geothermal	Wind	Waste	Wind	Waste
6	Waste	Waste	Biogas [geo thermal]	Solar (heat)	Geothermal
7	Biogas	Biogas	Geothermal [biogas]	Solar (light)	Biogas

4. Discussion

In this research, other than analyzing the overall consensus of the whole panel on the selection of appropriate RE source to provide energy assistance to North Korea, it also subdivided the panel into three sub-panels based on the panel member's expertise and characteristics. The three sub-panels were engineers, Korean political and security experts, and foreign political and security experts. The result was that this research was able to determine the differences in perspectives and interests of each sub-panel and how these differences influenced their preferences.

As we conducted our survey, we were able to conduct interviews with the panel members and gained numerous valuable perspectives, comments, and opinions from the panel members. Information gained during these interviews were not directly applied in our AHP analysis, but they were useful in identifying the overall inclination of the panel and the background/reason for their answers.

The survey result shows the panel placed most weight on *security* (0.541) among the strategic criteria, followed by *humanitarian* (0.250), and *political* (0.209) (Table 1), which meant that the panel as a whole showed it considers *security* issue as the most important reason to provide RE assistance to North Korea. Such result suggests that among several external factors that can influence RE assistance to North Korea, it would react to security issues with the highest sensitivity. The result also suggests that in the process of providing energy assistance, the factors that need to be examined with utmost attention are also those related to security.

For the Level 1 attributes, the weights were ordered *cost* (0.343), *benefit* (0.339), and *risk* (0.317) (Table 2). Although there were not a large differences between the weights of each attribute, *cost* was shown to have the highest weight, which means we could determine that *cost* was the attribute that the panel considered most important. In other words, the panel showed the tendency to reconsider providing assistance using a particular energy source even if the *benefit* or the *risk* are found to be appropriate if the *cost* is found to be not appropriate (or conversely, even if the *benefit* or the *risk* are found to be inappropriate if the *cost* is found to be appropriate).

The results for the Level 2 attributes are listed in Table 3. The attributes that received highest weights were: "B3: Improvement of inter-Korean relations" (0.108); "C2: Facility maintenance cost" (0.109); "C3: Related infrastructure construction cost" (0.132); "R1: Technology transfer problem" (0.132); and "R2: Appropriateness to North Korea" (0.112). The weights of the Level 2 attributes are the final weights that also reflect the weights of the Level 1 attributes.

Table 4 shows the priority preferences of each alternative based on the results shown in Tables 1–3. The panel selected *wind power* as the best alternative energy source to provide North Korea while *solar* (heat and light) and *small hydropower* followed in preferences. Using these results, one can ascertain what factors need to be focused on and considered as South Korea moves forward to develop, write, and implement policies on energy assistance to North Korea. Moreover, one can ascertain what matters need to be addressed and decided on first when faced with issues arising from South Korea's decision to move forward with its energy policies, as well as utilizing the opinions of the experts related to each alternative energy sources as references in development and implementation phases of the said policies using the results of this survey.

One must note, however, that depending on the composition and characteristics of the sub-panel, there were some minor differences in opinion (as shown in Tables 1–4). Hence, as these opinions of each sub-panel were combined and averaged to ascertain the values for the entire panel, some of the opinions that were unique to each of the sub-panels could have been slightly curtailed in the process.

4.1. Panel opinions: opinions on strategic criteria and level 1 attributes

Table 1 shows the panel's opinions on the *strategic criteria*. The results show that the panel as a whole, as well as sub-panels, placed the most weight on the *security* attribute although the degree of weight placed on the *security* attribute differed based on the sub-panel's characteristics. Engineers tended to place less weight on *political* and higher weight on *humanitarian*, meaning the members of this sub-panel viewed the reason for RE assistance to North Korea as a more humanitarian effort than a political endeavor. This tendency could be attributed to the engineers' general attitude that they are more interested in further technological development of their specific fields and the improvement of quality of life for the North Korean people than any political situation that may be involved with any energy assistance program. Engineers' such attitude was verified during the survey with their very high interest in the Level 2 attribute "B4" where it asked the panel about development of related industry in South Korea and energizing R&D of related technology n South Korea.

In contrast, the Korean political and security experts placed relatively less weight on *humanitarian* attribute and highest weight on *security*, implying that the South Korean political and security experts relate RE assistance to North Korea to the security of South Korean and less to humanitarian issue about North Korean residents.

Foreign political and security experts, on the other hand, placed less weight on *security* than the other two sub-panels, showing that their position is one step removed from their Korean counterparts and engineers. The foreign sub-panel placed higher weight on *political* and *humanitarian* attributes than the other two sub-panels.

In the mean while, foreign political experts weighed less to 'security' than other groups, which represents that their position to the South Korea security problem is a step backward. They weighed high to each of 'political' and 'humanitarian'.

Panels also placed their weights in differently for the Level 1 attributes, as shown in Table 2. The Korean sub-panels (engineers and political/security experts) placed more weight to *cost* than *risk*; however, the foreign sub-panel placed more weight on *risk* than *cost*. Additionally, the engineer sub-panel placed more weight on *cost* than *benefit*, but the political and security expert sub-panels (both Korean and foreign) placed more weight on *benefit.*

The panel's opinions for the level 2 attributes of *benefit* differed significantly. The engineers placed a high weight on B4 – development of related industry in South Korea – while the political and security experts (both Korean and foreign) placed almost no weight on B4. The Korean political and security experts placed heavy weight on B3 – improvement of inter-Korean relations – while the foreign political and security experts placed heavy weight on B1 – availability of energy source within North Korea. These answers point to the tendency that the engineers were interested in development of their own technological field while the Korean political and security experts were interested in the *benefit* to South Korea, and the foreign political and security experts were more interested in the *benefit* North Korea would receive from the energy assistance (Table 3).

Differences between the sub-panels for *cost* showed to be very interesting. The engineers and the political/security experts presented conflicting opinions when it came to the issue of *cost*. The engineers placed the heaviest weight on C1 – facility construction cost – while the political and security experts placed the least weight on C1. The political and security experts placed the heaviest weight on C2 – facility maintenance cost – while the engineers placed the lowest weight on C2 (Table 3).

There were some distinct differences for level 2 attributes of *risk* as well. The engineers and foreign political/security experts placed high weight on R1 – technology transfer problems – while the Korean political and security experts did not. The engineers' tendency to place high weight on R1 was found to be due to their desire to protect the technological advantage. Additionally, the survey showed the engineers placed low weight on R2 – appropriateness to North Korea – while both Korean and foreign political and security experts placed heavier weight on R2.

The survey showed the panel as a whole preferred wind, solar (light), solar (heat), and small hydropower as the top four (in priority order) alternative energy sources. The results showed there were only small differences in preference between the first and the fourth preferred alternatives. The fist to fourth alternatives

showed to have the weights between 3.92 and 3.32; however, the fifth through seventh alternatives (geo thermal, waste, and biogas) received the weights between 2.24 and 2.68, showing a large gap with the weights first through fourth alternatives received. The preference of the total panel was similar to the preference order of the foreign political and security expert sub-panel. The preference of the total panel was also similar to the preference order of the engineer sub-panel with the exception of the wind and geo thermal alternatives; however, the preference of the total panel was significantly different from the Korean political and security expert sub-panel's preference order. The results showed that there were significant differences in the each sub-panel's opinion on what alternative energy source to provide to North Korea based on the sub-panel's expertise, perspective, position, and nationality.

4.2. Sub-panel opinion: engineers

For the engineer sub-panel, the calculated weights of the level 1 attributes were *cost* (0.41), *benefit* (0.30), and *risk* (0.29) respectively (Table 2). The results showed that the engineers placed the highest weight on *cost* and then on *benefit* and *risk*, and what showed to be of significance was that the level of weight placed on *cost* by the engineers was much higher than those placed by the political and security experts. Regardless of nationality, the political and security experts placed similar weights between all three attributes, but the engineers especially placed heavy weight on *cost*. Among the *cost*, the engineers selected facility construction cost as the most important while the political and security experts selected facility construction cost as the least important factor.

The engineers, not to anyone's surprise, showed to be very sensitive to the issues related to technology. This tendency of the engineers could be seen in their selection of B4 – development of related industry in South Korea – and R1 – technology transfer problem – (Table 3) as one of the most weighted attributes. Among the *strategic criteria*, the engineer placed highest weight on *security* and low weight to *political* factors (Table 1).

This characteristic of the engineer sub-panel was shown during the final selection of the alternative energy sources as well. The engineers gave low weight to biogas and wind power, which are both currently actively used in North Korea (Table 4). Of various alternative energy sources, North Korea is already actively engaged in utilizing and developing wind, small hydropower, waste and biogas technologies, but North Korea is not actively engaged in developing solar power (light and heat) [10]. The engineers showed to prefer providing North Korea with the technology that has a higher possibility of future development rather than the technology that is already being used in North Korea. This preference of the engineer sub-panel can be interpreted to show the engineers' expectations that RE assistance to North Korea could provide an opportunity to advance technological research and development in South Korea.

During the survey, the engineers pointed out that the construction cost for waste and biogas facilities is high and the construction of infrastructure related to waste and biogas facilities must be conducted simultaneously. They also forecasted that obtaining waste and biomass to sustain the operation of the facilities would be difficult in the long-term given the economic and agriculture situation of North Korea.

North Korea, however, already makes use of methane extracted from fermented biomass from the farming areas as heating fuel and alternative fuel source for vehicles. In 2003, the *Pyongyang Broadcasting Station* reported that the Ryuhyun Cooperative Farm located in the Yeokpo district of Pyongyang has been using methane gas collected from biomass as heating fuel. There are other examples of biogas use around North Korea as well. Over 700 houses of the Ryongsan Collective Farm already use methane extracted from biomass, and other collective farms located in Yeokpo and Soshin are working to use biogas as heating fuel. Additionally, collective farms located in the City of Sariwon and Migok already use biogas for heating fuel [28,29].

North Korea, suffering from chronic electricity shortage, is also aggressively pursuing the development of wind power technology. Wind power is seen as the most plausible alternative power source as the electricity generated from hydroelectric power plants decreases during the winter. Moreover, the US was known to have considered providing North Korea with wind power technology as a part of the energy assistance plan of the 13 February agreement [29–31].

Although wind power and biogas are two alternative energy sources that North Korea is already developing, the engineers placed higher plausibility for support on the technology that is not currently being used in North Korea rather than those that are already in use. This tendency can only be interpreted as the engineers' desire to use the RE assistance to North Korea as an opportunity to further conduct RE technology R&D for the South Korean industries with no consideration to what is actually appropriate for meeting North Korean needs.

Overall, the engineer sub-panel's opinions are clearly different from other sub-panels' opinions, and this seems to be due to the fact that issues of technological development, industrial expansion, and technology transfer are the most important factors from engineers' perspectives.

4.3. Sub-panel opinion: Korean political and security experts

The Korean political and security experts presented the exact opposite perspectives from the engineers. The Korean political and security experts placed the most weight on *security* and the least weight on *humanitarian* among the *strategic criteria* (Table 1). The engineer (composed of Korean engineers) and foreign political/security expert sub-panels placed the most weight on *security* and selected *humanitarian* as having next weight while the Korean political and security experts placed more weight on *political* than on *humanitarian*. The Korean political and security experts placed heavier weight on *security* than other expert sub-panels. This implies that national and regional security is of paramount concern from the Korean political and security experts' perspective.

The Korean political and security experts placed highest weights on B3 – improvement of inter-Korean relations – and R2 – appropriateness to North Korea (Table 3). This result shows their belief that the greatest effects of energy assistance to North Korea is improvement of inter-Korean relations. Additionally, this sub-panel thought R2 – appropriateness to North Korea – was more important than R1 – technology transfer problem – or R3 – technological availability and readiness in South Korea. Also different from the engineer sub-panel, the Korean political and security sub-panel preferred to supply small hydropower [32,33], waste [28], and biogas [28,29] as RE source of assistance to North Korea, which are all technologies that are already being used in North Korea. While the engineers placed lowest weight to biogas, the Korean political and security experts placed biogas third out of all the alternatives (Table 4).

During the interview, we were able to ascertain that the Korean political and security experts tended to view the issue of energy assistance to North Korea from the possibility of technology transfer perspective; thus, they tended to react sensitively to the possibility of any assistance provided to North Korea being diverted for non-peaceful use although they did agree with providing energy assistance to North Korea for political, security, and humanitarian reasons. They pointed out, for example, possibility of the North Korean military using RE facility for military purposes (i.e. using solar power panel for military

purpose), or using electricity generated by donated RE facility for non-peaceful means. Accordingly, the Korean political and security experts opined that for R1 – technology transfer problem, solar (light) power is the energy source that is most likely to have problems with technology transfer.

The Korean political and security experts preferred to provide North Korea with alternatives that have less chance of technology transfer issues, such as small hydropower, waste, and biogas. The tendency that they gave such a high priority to waste and biogas, which the engineers shied away from due to problems associated with infrastructure construction, can also be found in the way they placed high weight in C3 – related infrastructure cost (among the level 2 attributes for *cost*). During the interviews, they all implied that for any energy assistance to North Korea to be successful, the infrastructure problem must be solved first, and ultimately, adequate infrastructure must be constructed in North Korea in preparation for unification and to build a sustainable energy system in the long-run. Therefore, they believe that if an alternative provides higher *benefit*, and the *cost* is less important in selection of that alternative. For this group, the calculated weights for level 1 attributes were *benefit* (0.38), *cost* (0.32), and *risk* (0.29), respectively. While both Korean and foreign political and security expert sub-panels placed highest weight on *benefit*, the Korean sub-panel placed next highest weight on *cost* and the foreign sub-panel placed it on *risk*. There were clear differences in *cost* among the three sub-panels as well. The Korean sub-panel placed more weight on *infrastructure construction* while the foreign sub-panel placed it on *facility maintenance cost*, and the engineers went for *facility construction cost*.

The survey results showed that the Korean political and security experts preferred to provide RE assistance using RE alternatives that can be easily adopted to North Korea's environment and those that have already been in discussion inside South Korea (Table 4). This view point is significantly different than those of the engineer or foreign political and security experts. Additionally, it is also different than the overall panel's view point. The Korean political and security experts believed the most important factor in providing RE assistance to North Korea is *security* and when the assistance is implemented, expected *benefit* should be the most important factor considered. Moreover, since the improvement in inter-Korean relations through the RE assistance is important for this sub-panel, it is highly appropriate that they would believe the RE source selected should be one that is appropriate to current North Korean situation and the infrastructure construction issues must also be considered.

4.4. Sub-panel opinion: foreign political and security experts

The foreign political and security experts rated the *strategic criteria* in following order: *security*, *humanitarian*, and *political*. The weight placed on *security*, however, was the smallest among the three sub-panels. This implies that this sub-panel regarded *security* as the most important factor compared to other factors of the *strategic criteria*, but the degree of importance is not high relative to other factors. This sub-panel placed higher weight on *humanitarian* than other sub-panels (Table 1).

The foreign political and security experts placed the highest priority on *benefit*, especially on B1 – availability of energy source within North Korea. This survey result is consistent with the foreign political and security experts placing highest priority on *humanitarian* factor of *strategic criteria*. In the area of *risk,* they gave the highest weight to R1 – technology transfer problem – and R2 – appropriateness to North Korea (Table 3). This result was distinctive from the Korean political and security expert sub-panel where it did not consider R1 to be a serious factor.

The foreign sub-panel selected wind, solar (light), and solar (heat), as the top three alternative energy sources appropriate to provide North Korea as a part of energy assistance (Table 4). Although the foreign sub-panel also reacted sensitively to the issue of technology diversion, similar to the Korean sub-panel, the foreign sub-panel preferred wind, solar (light), and solar (heat) because there has not been any incident where North Korea has diverted RE for non-peaceful use, and that this fact serves as a point of trust with North Korea. In fact, in September 2005, the Nautilus Institute installed two wind pumps for irrigation in Unha-Ri, Oncheon County, and this case received the best reviews by the sub-panel [34–36]. Solar (light) and solar (heat) technology provided by World Vision, EMI, and other organizations of Korea and Japan received the next favorable reviews from the sub-panel. The foreign sub-panel opined that wind power is most appropriate because it satisfies factors B1 – availability of energy source within North Korea, B2 – area development of North Korea, B3 – improvement of inter-Korean relations, C1 – facility construction cost, R2 – appropriateness to North Korea, and R3 – technological availability and readiness in South Korea. On the other hand, the foreign sub-panel was not interested in providing North Korea with RE sources such as small hydropower and waste because these sources are already being used and developed internally by North Korea. The reason for this seems to be that considering this is an "assistance" provided to North Korea, there is no real merit in providing something that North Korea already has as well as because there are very few cases where these sources were provided as energy assistance in the past.

The foreign sub-panel was more interested in humanitarian aid and resolution of the North Korean nuclear problem than other sub-panels. They insisted that although unilateral South–North energy assistance is important, if South Korea is going to end up shouldering all the cost of such assistance, then including other countries within and without the region, such as China, the US, and EU, should also be considered.

For the foreign political and security experts, humanitarian aid was the most important reason for providing North Korea with energy assistance and the improvement of inter-Korean relationship was next in priority. Moreover, the foreign sub-panel believed the resolution of the North Korean nuclear problem is a prerequisite to any improved relations – implying that the foreign sub-panel viewed *security* issues with more significance than the Korean sub-panel. The calculated weights for the foreign political and security experts were *benefit* (0.35), *risk* (0.34), and *cost* (0.32), respectively.

5. Conclusion

This research was conducted under the theoretical base of the AHP-BOCR. The result is more reliable than the previous researches conducted on this similar topic because of the theoretical underpinnings this analysis was based on. AHP method as described above provides a comprehensive framework for decision-making. Thus, it helps to achieve the purpose of this study efficiently with high reliability.

This study also has distinct characteristics to other studies that it includes a panel of experts with international relations, international security, and North Korean policy. Panels of the previous studies only included the opinions of those experts who have expertise in RE. In order to truly determine the sustainable RE source for North Korea, however, inclusion of expert views of those whose expertise are in international relations, international security, and North Korean policy are an absolute must. Although these policy and security experts may not be able to answer the technical issues related to the implementation of RE, but they can provide insights into the North Korean internal affairs, uniqueness

in dealing with North Korea, and international relations considerations when addressing North Korean issues.

Another very large difference for this study from the previous studies is that this study included the views of foreign experts as well as the Korean experts to compare the two group's difference in perspectives and positions. Including foreign experts' views is essential in developing the South Korean policy on energy assistance to North Korea because to effectively provide energy assistance to North Korea, an international consensus must be built and the international community must participate in the assistance program, for the North Korean energy problem is not simply a Korean Peninsula problem, but a regional and a global problem. Hence, by including the perspectives of the foreign experts, this study serves as a starting point in designing appropriate RE assistance policy for North Korea not only for South Korean internal purposes, but also for convincing the international community on the need for such a policy. Our panels were composed of both foreign experts in RE, international relationship, international security, political policy, and North Korea, and we were able to analyze the varying positions and perspectives on providing RE assistance to North Korea.

Through this study, it was found that RE assistance for North Korea can be consummated in several ways – technology cooperation, financial support, equipment installation, direct support, etc. It was also found that depending on which method the South Korean government decides to pursue, the composition of the expert panel must be adjusted to provide appropriate input to the policy writers.

We also found that panels consider international security factor more important than humanitarian factor or the political factor. We were able to determine this from the answers the panels provided for the strategic criteria. All the panels gave the security factor almost twice the weight than both political and humanitarian factors. In explaining the panels' attitudes toward energy assistance to North Korea, this result means the experts were more interested in instability on the Korean Peninsula and the possible worsening of the North Korean nuclear issue brought about by the sudden collapse of the North Korean regime rather than political differences between North and South Korea, public opinions of the South Korean citizenry, or the North Korean residents' plight due to lack of energy. Given the weight placed on the strategic criteria, this study purport this result should be reflected in any future South Korean policy on energy assistance to North Korea.

Unlike other researches that used AHP in their analyses, this research was not able to provide the final answer that could be used to apply directly to policy development and implementation. This was due to the fact that there were significant differences between the overall panel's and each sub-panel's opinions and final selections. Hence, for this research to have a meaning, the following points must be brought forth. First, AHP analysis is conducted by surveying a relatively small number of experts compared to other survey methods. This is possible because AHP assumes a certain basic level of consensus exists among the panel members; therefore, since diverse opinions exist among the experts of different expertise, if consensus can be built among these different groups through robust discussion and collaboration related to RE assistance to North Korea, we expect there would be a much better results for future research.

Additionally, there is a need for more open discussion on North Korean issues and more accurate information on RE and other information associated with RE and North Korea. Currently, due to the special characteristic that comes with being a divided country, it is very difficult to gain access to date on North Korea from the South. As a result, accurate data and information related to the North Korean environmental and infrastructure status are woefully lacking. Since there is a lack of any accurate data, robust discussion and collaboration cannot occur among the experts of different disciplines. This is one of many areas that need to be improved in the future.

Another point can be made on this. We have found that there were large differences between the perspectives and positions of experts in different disciplines that are too far to bridge. Experts of each discipline showed distinctly different priorities and their opinions have their own relevance and importance; therefore, a policy implication is that these different characteristics should all be considered and their appropriate views reflected in writing different policy alternatives. Despite such divergent views and the fact that this research was not able to recommend a single RE source to provide to North Korea as a RE assistance program, by surveying the preferences for RE assistance to North Korea of both Korean and foreign experts, we expect that this research will serve as an excellent reference for all future research on this topic.

This research should be supplemented in the future with ways the cost for energy assistance program to North Korea can be arranged and funded. The solution of the problem is beyond this study but it has to be solved if sustainable energy assistance is to be implemented for North Korea. Previous studies insist that South Korea bearing all the burden of the cost in providing technology, know-how, and funding to North Korea is more realistic than inter-Korean copayment [37–39]. Yet, other studies found that the South Korean people have no desire to pay directly the cost related to providing North Korea with energy [9,40,41]. Hence, there must be a follow-on study that fully explores realistic and effective ways to fund the required cost.

There are also a need for future studies that examine the energy assistance options based on different North Korean scenarios. For example, a study must be conducted for a scenario where North Korea gives up its nuclear arsenal and opens itself to the outside world. If this were to happen, the demand for industrial and transportation energy sources in North Korea will most likely sky rocket. With this premise, a study that considers usefulness and limitations of the RE in energy mix situation with traditional energy sources such as gas, thermal power, etc., guarantees to be a meaningful study.

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